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SCIENTIFIC EDITORIAL

Speckle-tracking strain echocardiography: Any place in routine daily practice in 2014?



Échocardiographie de déformation par *speckle-tracking*: quelle place en pratique clinique routinière en 2014?

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Myocardial fibres of the left ventricle (LV) have a spiral orientation, the subendocardial and subepicardial fibres being longitudinally orientated and the midwall fibres being circumferentially orientated. As a result, during normal systole, there is longitudinal myocardial shortening, which causes the left ventricular (LV) base to descend toward the apex, and there is circumferential shortening. The systolic (radial) thickening results from both longitudinal and circumferential shortening due to mass conservation of the myocardium. The LV also has a twist motion due to systolic counterclockwise rotation of the apex and clockwise rotation of the base. This complex motion leads blood to be propelled forward at a rate appropriate for organ perfusion and bodily function. This movement can be quantified by calculating myocardial strain, which describes myocardial deformation (i.e. the fractional change in the length of a myocardial segment during the cardiac cycle).

Speckle-tracking imaging is a relatively new technique for obtaining myocardial strain based on the tracking of speckles in gray-scale echocardiographic images. The speckles result from the interference of the ultrasound waves with structures smaller than the wavelength of the ultrasound. Speckles are acoustic markers that can be tracked from frame to frame (speckle correlation), allowing strain calculation. This approach has been validated experimentally against micrometry and cardiac magnetic resonance imaging (MRI) [1]. The optimal frame rate for speckle-tracking strain assessment is 50–90 frames/second. Indeed, higher frame rate values lead to a decrease in the number

Abbreviations: 2D, two-dimensional; 3D, three-dimensional; DICOM, Digital Imaging and Communications in Medicine; GLS, global longitudinal strain; LV, left ventricle/ventricular; LVEF, left ventricular ejection fraction; MRI, magnetic resonance imaging.

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of ultrasound beams in each frame, resulting in low spatial resolution and poor image quality. Conversely, low frame rates may result in a loss of speckles, as they can move out of plane in successive frames. Longitudinal strain can be obtained at a segmental level in apical views; circumferential and radial strain can be obtained in parasternal views (Fig. 1).

Global longitudinal strain (GLS) is the average longitudinal component of strain in the entire myocardium, which can be approximated by averaging the segmental strain components in individual myocardial wall segments [2]. The reproducibility of GLS was excellent in previous reports (with coefficients of variation of about 7%), but reproducibility was significantly lower for circumferential strain and even worse for radial strain [3]. One explanation may be that the LV shortens from base to apex with systole, hence complicating the fixed short-axis tracking that is required for radial and circumferential strain. In contrast, the heart moves from base to apex within the same plane in case of longitudinal tracking. Recently, in a cohort of consecutive patients in daily practice, longitudinal strain was reliably obtained in 90% of segments but circumferential and radial strain were obtained in only half of the patients [4]. Vendors have accordingly developed intuitive toolboxes that allow rapid online quantification of longitudinal strain. Segmental systolic longitudinal strain is commonly represented on an American Society of Echocardiography 17-segment bull's eye diagram or on time-dependent curves of strain throughout the cardiac cycle (Fig. 2).

Studies have demonstrated the clinical relevance of speckle-tracking GLS in a variety of clinical settings. In a retrospective study of 546 consecutive individuals in an academic echocardiography laboratory, GLS was a superior predictor of outcome compared with left ventricular ejection fraction (LVEF) and wall score motion index. GLS provides independent prognostic information compared with LVEF in patients with heart failure and LV systolic dysfunction [5]. The combination of longitudinal strain and wall motion score index provides a significant incremental increase in diagnostic accuracy for coronary artery disease [6]. Impaired GLS is associated with outcomes in patients with valvular heart disease such as organic mitral regurgitation [7] and severe asymptomatic aortic stenosis [8]. GLS identifies subclinical disease in patients with diabetes or cardiomyopathies [9,10]. In addition, GLS is an independent early predictor of subsequent reductions in LVEF, incremental to the usual predictors in patients at risk of trastuzumab-induced cardiotoxicity [11]. Despite these important findings, previous reports have demonstrated significant differences between vendors for GLS values obtained by speckle-tracking in patients with normal and with pathological findings [12,13]. Vendor-specific methods for processing LVEF in apical views with divergent results in the past may have definitively compromised the use of this index, which plays a major role in decision-making in everyday cardiology practice. Post-processing and speckle-tracking algorithms that are vendor specific appear to be the most important determinant in intervendor variation. In contrast, image acquisition appears to have only a limited effect [12]. However, in a recent meta-analysis of normal ranges of LV strain, blood pressure – but not the vendor – was associated with variations in normal GLS values [14].

Given the potential discrepancy between vendors, which could compromise the widespread clinical use of speckle-tracking strain, the American Society of Echocardiography and the European Association of Echocardiography have set up an expert group, comprising interested researchers and industry members, to achieve concordance concerning the details of what is measured by these techniques. Phantoms are used to calibrate strain values. Let us hope that this important work will result in standardization of GLS values in the near future. Another alternative would be to use vendor-independent software products on images recorded in the Digital Imaging and Communications in Medicine (DICOM) format. However, the main limitation is the low frame rate (30 frames/second) in the DICOM format, potentially leading to undersampling and speckle decorrelation. This is not a limitation of vendor-specific software products, which use raw data with the native frame rate.

Another important limitation of GLS in daily practice is that advances in echocardiography for quantification of cardiac structure and function have not been seen in clinical trials, despite the modest interobserver reproducibility of conventional measures of LV systolic function. GLS may be used for functional assessment of the LV, as an endpoint for the evaluation of the effect of drugs or devices on the LV. For example, indications for cardiac resynchronization therapy or an implantable cardioverter defibrillator rely on LVEF due to inclusion criteria in large clinical trials. The effect of CRT on LV remodelling relies on changes in LV volumes or LVEF, despite their low reproducibility, but not on changes in GLS. Interestingly, a very recent study has demonstrated the excellent feasibility and reproducibility of GLS measurement in the context of an epidemiological community-based study [15].

How to integrate longitudinal strain values into our daily practice in 2014?

First, GLS measurement relies on acquired cine loops with optimal quality, with particular care required to avoid apical foreshortening. Hence, GLS measurement enhances our echocardiographic skills to obtain reliable apical two-dimensional (2D) views and increases the global echocardiographic imaging quality. From a practical approach, the use of a single apical view to derive longitudinal strain is not recommended, as strain may be segmentally decreased while GLS remains preserved, with important clinical implications. Hence, GLS values should be reported in the echocardiographic report. It is worth noting that blood pressure must be measured at the time of echocardiography and reported, as it influences longitudinal strain values. A "normal" GLS value was -19.7% (95% confidence interval -20.4% to -18.9%) in a recent meta-analysis. From a practical point of view, a cut-off value of -17% should be considered for "abnormal longitudinal strain". Whether age-dependent strain values should be used is a matter of debate [16].

The second step is to quickly analyse the bull's eye recording by pattern recognition. For example, cardiac amyloidosis is responsible for a decrease in basal longitudinal strain with relative apical sparing, as shown in Fig. 3A

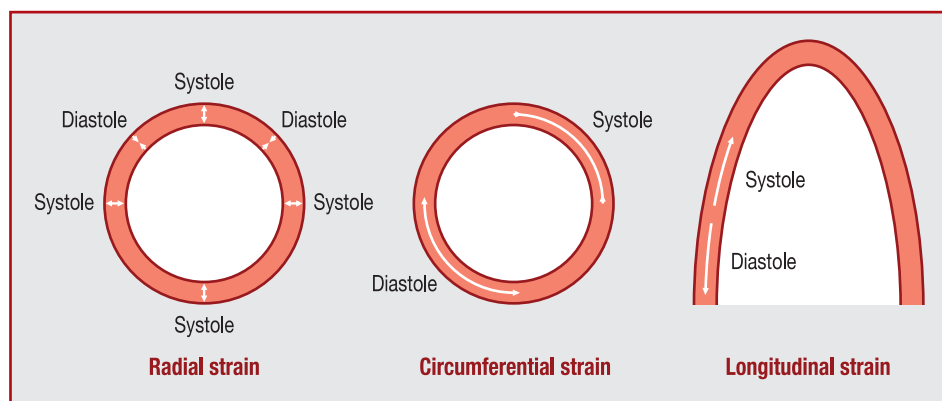


Figure 1. The three components of strain (longitudinal, radial and circumferential).

[17]. Similarly, asymmetric septal hypertrophic cardiomyopathy is characterized by a decrease in septal longitudinal strain (Fig. 3B). In some cases, zones of chronic myocardial infarction may be recognized as contiguous segments with markedly abnormal strain (Fig. 3C and 3D). It is worth noting that an isolated markedly abnormal strain segment may be found, with no adjacent abnormal segments and a visually normal echocardiogram; such a finding corresponds to a “false-positive” strain echocardiogram (Fig. 4).

More complicated approaches, including analysis of multiwave forms of longitudinal, radial and circumferential strain measurements and LV twist are more cumbersome for clinical practice, but are very valuable research tools for understanding the pathophysiology of cardiac diseases. For example, waveform interpretation is particularly difficult in patients with coronary artery disease in the setting of acute coronary syndrome or in the chronic phase of myocardial infarction for the assessment of myocardial viability. Peak strain can be measured as peak systolic strain

(positive or negative), peak strain at end-systole (at the time of aortic valve closure) or peak strain regardless of timing (in systole or early diastole). In the setting of myocardial infarction, peak systolic strain better correlates with late-enhancement MRI findings [18]. In contrast, in patients with left bundle branch block, peak strain regardless of timing should be used, as the maximal deformation of the lateral wall is after aortic valve closure, while the maximal deformation of the septal wall may be presystolic [19].

Previous reports have highlighted the importance of longitudinal and circumferential strain for detecting acute coronary occlusion in non ST-segment elevation myocardial infarction or for detecting the transmural of myocardial infarction compared with late-enhancement cardiac MRI [20]. In Fig. 5, we present the case of a 65-year-old patient referred to the emergency department for persistent chest pain with a normal electrocardiogram. Decreased longitudinal strain in the inferolateral and anterolateral territories (Fig. 5A) correlated with a circumflex artery

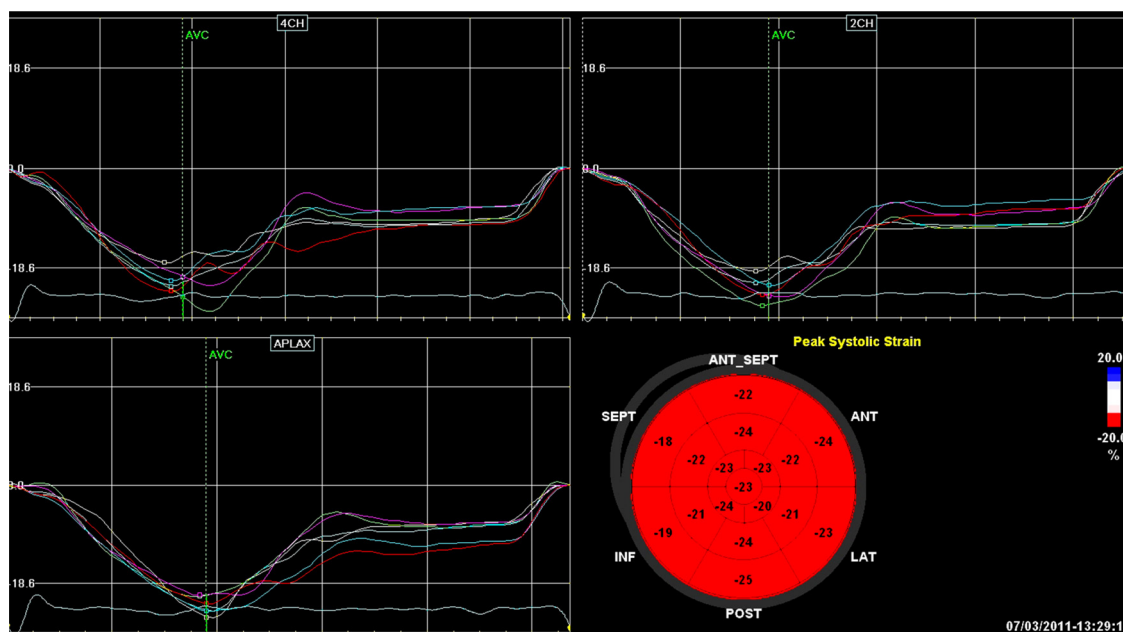


Figure 2. Segmental strain curves and the 17-segment bull's eye representation of longitudinal strain.

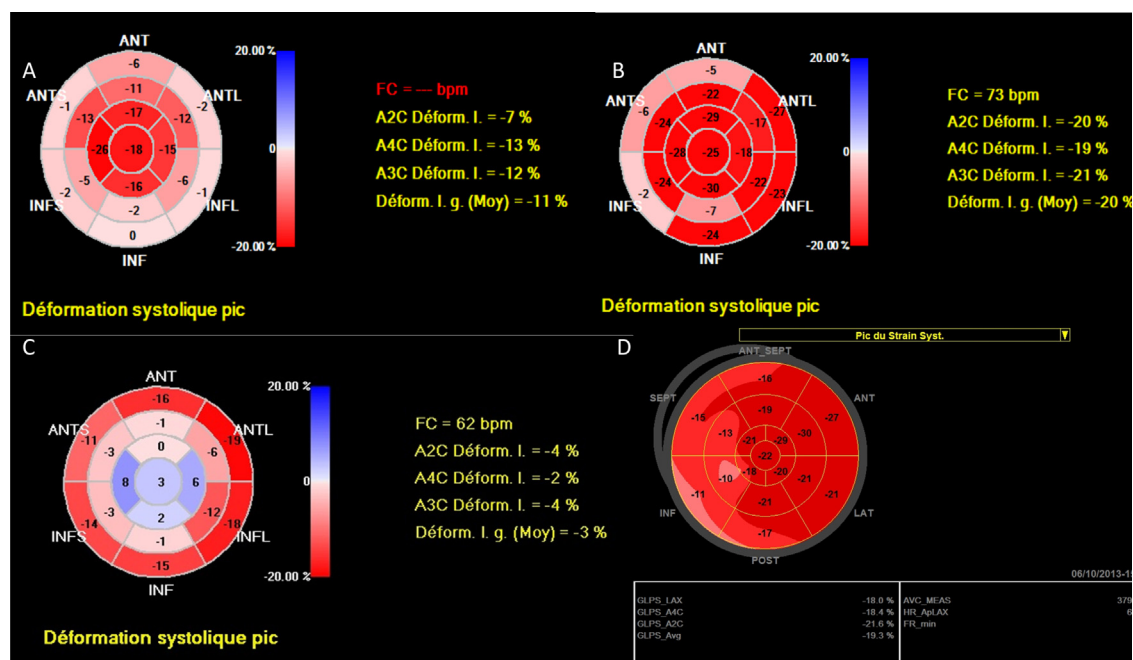


Figure 3. Bull's eye representation of longitudinal strain in a patient with: (A) cardiac amyloidosis; (B) septal hypertrophic cardiomyopathy; (C) chronic large anterior myocardial infarction; and (D) chronic inferior myocardial infarction.

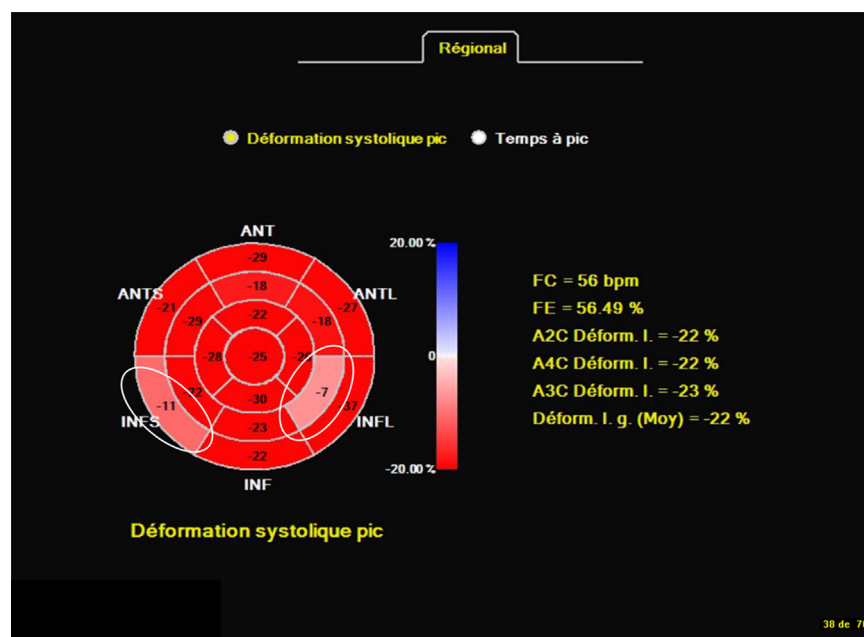


Figure 4. Two isolated segments (white circles) with markedly abnormal longitudinal strain in a patient with a normal echocardiogram, indicating false-positive results. Note that global longitudinal strain is within the normal range.

occlusion (Fig. 5B). Strikingly, the performance of longitudinal strain was lower than circumferential strain in this setting, with substantial overlap between pathological and reference groups. Recently, the assessment of layer-specific longitudinal strain identified non-ST-segment elevation acute coronary syndrome patients with significant coronary artery disease [21]. Endocardial function was more severely affected in patients with significant coronary artery disease compared with epicardial function and LVEF. The assessment of subendocardial strain using new

layer-specific longitudinal strain software products may refine the role of longitudinal strain in this important clinical setting.

Speckle-tracking strain can be obtained with three-dimensional (3D) echocardiography. From a theoretical viewpoint, 3D-derived strain overcomes one of the limitations of 2D strain (i.e. out-of-plane motion of the speckles). Hence, 3D-strain echocardiography may represent an interesting alternative approach for the assessment of circumferential and radial strain. Three-dimensional area

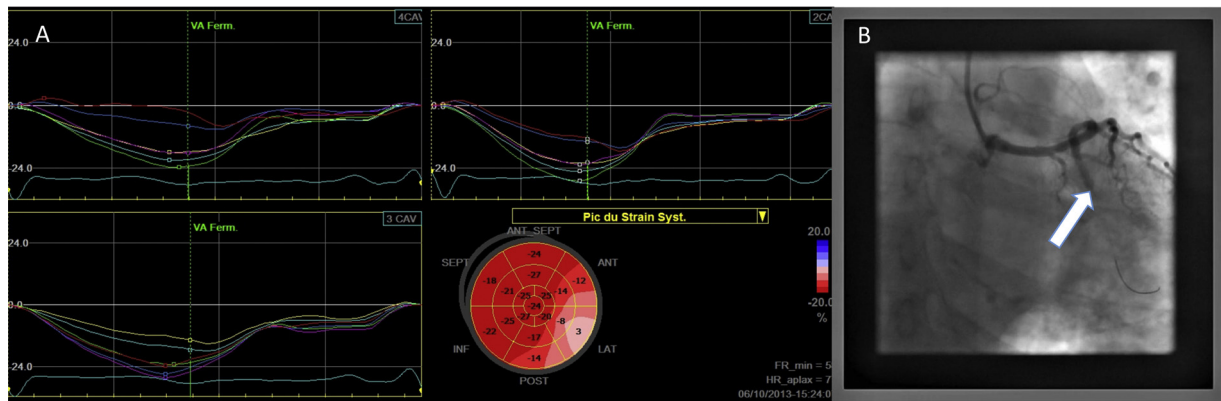


Figure 5. The case of a 65-year-old patient with acute chest pain and a near-normal electrocardiogram. Despite no clear wall motion abnormality at visual inspection, longitudinal strain is decreased in the territory of the left circumflex artery (A), which was occluded at coronary angiography (B).

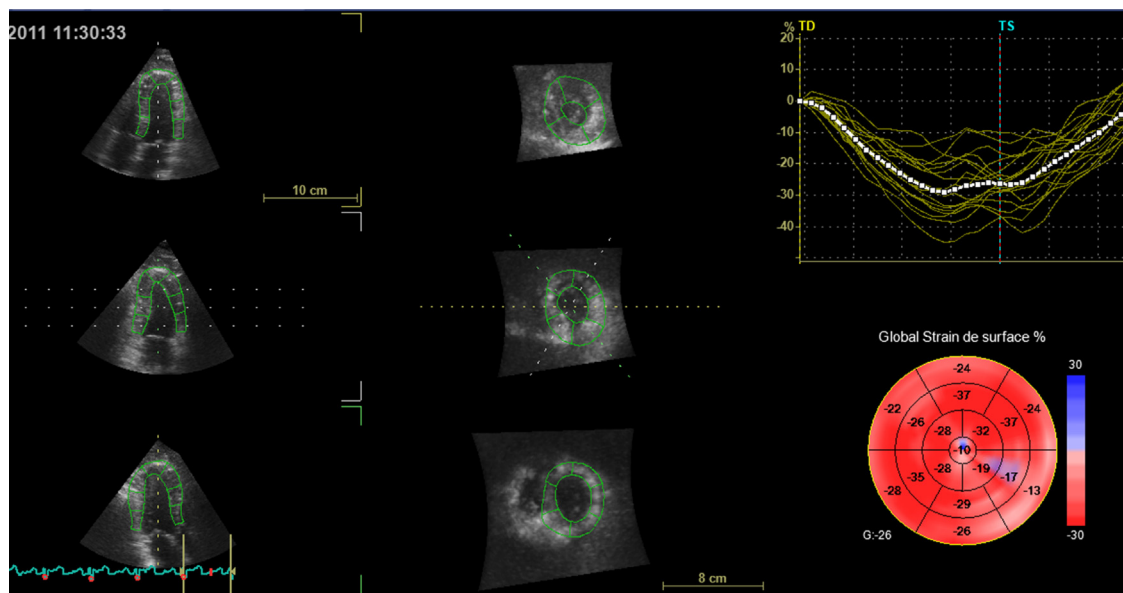


Figure 6. Three-dimensional speckle-tracking area strain in a normal patient with segmental curves and 17-segment bull's eye representations.

strain, which integrates all components of strain (longitudinal, radial and circumferential), can be obtained (Fig. 6); it is reproducible and correlates better with LVEF than 2D-strain data [22]. The main limitation in clinical practice is feasibility (around 75%), as there is a need for breath-hold during six cycles to obtain a volume rate greater than 40 frames/second. Arrhythmias or poor echogenicity are also other issues. However, 3D speckle-tracking is likely to represent the future of speckle-tracking once smaller probes with higher frame rates obtained within one cycle are released. Hence, 2D longitudinal strain is likely to remain the strategy of choice for strain imaging in the immediate future.

Disclosure of interest

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References

- [1] Amundsen BH, Helle-Valle T, Edvardsen T, et al. Noninvasive myocardial strain measurement by speckle tracking echocardiography: validation against sonomicrometry and tagged magnetic resonance imaging. *J Am Coll Cardiol* 2006;47:789–93.
- [2] Mor-Avi V, Lang RM, Badano LP, et al. Current and evolving echocardiographic techniques for the quantitative evaluation of cardiac mechanics: ASE/EAE consensus statement on methodology and indications endorsed by the Japanese Society of Echocardiography. *J Am Soc Echocardiogr* 2011;24:277–313.
- [3] Serri K, Reant P, Lafitte M, et al. Global and regional myocardial function quantification by two-dimensional strain: application in hypertrophic cardiomyopathy. *J Am Coll Cardiol* 2006;47:1175–81.
- [4] Villanueva-Fernandez E, Ruiz-Ortiz M, Mesa-Rubio D, et al. Feasibility of bidimensional speckle-tracking echocardiography for strain analysis in consecutive patients in daily clinical practice. *Echocardiography* 2012;29:923–6.

- [5] Stanton T, Leano R, Marwick TH. Prediction of all-cause mortality from global longitudinal speckle strain: comparison with ejection fraction and wall motion scoring. *Circ Cardiovasc Imaging* 2009;2:356–64.
- [6] Ng AC, Sitges M, Pham PN, et al. Incremental value of 2-dimensional speckle tracking strain imaging to wall motion analysis for detection of coronary artery disease in patients undergoing dobutamine stress echocardiography. *Am Heart J* 2009;158:836–44.
- [7] Magne J, Mahjoub H, Dulgheru R, et al. Left ventricular contractile reserve in asymptomatic primary mitral regurgitation. *Eur Heart J* 2013, <http://dx.doi.org/10.1093/eurheartj/ehs345> [in press].
- [8] Yingchoncharoen T, Gibby C, Rodriguez LL, et al. Association of myocardial deformation with outcome in asymptomatic aortic stenosis with normal ejection fraction. *Circ Cardiovasc Imaging* 2012;5:719–25.
- [9] Ernande L, Rietzschel ER, Bergerot C, et al. Impaired myocardial radial function in asymptomatic patients with type 2 diabetes mellitus: a speckle-tracking imaging study. *J Am Soc Echocardiogr* 2010;23:1266–72.
- [10] Richand V, Lafitte S, Reant P, et al. An ultrasound speckle tracking (two-dimensional strain) analysis of myocardial deformation in professional soccer players compared with healthy subjects and hypertrophic cardiomyopathy. *Am J Cardiol* 2007;100:128–32.
- [11] Negishi K, Negishi T, Hare JL, et al. Independent and incremental value of deformation indices for prediction of trastuzumab-induced cardiotoxicity. *J Am Soc Echocardiogr* 2013;26:493–8.
- [12] Negishi K, Lucas S, Negishi T, et al. What is the primary source of discordance in strain measurement between vendors: imaging or analysis? *Ultrasound Med Biol* 2013;39:714–20.
- [13] Sun JP, Lee AP, Wu C, et al. Quantification of left ventricular regional myocardial function using two-dimensional speckle tracking echocardiography in healthy volunteers – a multicenter study. *Int J Cardiol* 2013;167:495–501.
- [14] Yingchoncharoen T, Agarwal S, Popovic ZB, et al. Normal ranges of left ventricular strain: a meta-analysis. *J Am Soc Echocardiogr* 2013;26:185–91.
- [15] Cheng S, Larson MG, McCabe EL, et al. Reproducibility of speckle-tracking-based strain measures of left ventricular function in a community-based study. *J Am Soc Echocardiogr* 2013, <http://dx.doi.org/10.1016/j.echo.2013.07.002> [pii: S0894-7317(13)00535-X; Epub ahead of print].
- [16] Zghal F, Bougteb H, Reant P, et al. Assessing global and regional left ventricular myocardial function in elderly patients using the bidimensional strain method. *Echocardiography* 2011;28:978–82.
- [17] Phelan D, Collier P, Thavendiranathan P, et al. Relative apical sparing of longitudinal strain using two-dimensional speckle-tracking echocardiography is both sensitive and specific for the diagnosis of cardiac amyloidosis. *Heart* 2012;98:1442–50.
- [18] Sjolli B, Orn S, Grenne B, et al. Diagnostic capability and reproducibility of strain by Doppler and by speckle tracking in patients with acute myocardial infarction. *JACC Cardiovasc Imaging* 2009;2:24–33.
- [19] Risum N, Jons C, Olsen NT, et al. Simple regional strain pattern analysis to predict response to cardiac resynchronization therapy: rationale, initial results, advantages. *Am Heart J* 2012;163:697–704.
- [20] Grenne B, Eek C, Sjolli B, et al. Acute coronary occlusion in non-ST-elevation acute coronary syndrome: outcome and early identification by strain echocardiography. *Heart* 2010;96:1550–60.
- [21] Sarvari SI, Haugaa KH, Zahid W, et al. Layer-specific quantification of myocardial deformation by strain echocardiography may reveal significant CAD in patients with non-ST-segment elevation acute coronary syndrome. *JACC Cardiovasc Imaging* 2013;6:535–44.
- [22] Reant P, Barbot L, Touche C, et al. Evaluation of global left ventricular systolic function using three-dimensional echocardiography speckle-tracking strain parameters. *J Am Soc Echocardiogr* 2012;25:68–79.